AMERICAN SOCIETY OF HEATING, REFRIGERATING

AND AIR-CONDITIONING ENGINEERS, INC.

1791 Tullie Circle, NE Atlanta, GA 30329 404-636-8400

TC/TG/TRG MINUTES COVER SHEET

(Minutes of all meetings are to be distributed to all persons listed below

within 60 days following the meeting.)

TC/TG/TRG NO. TC4.11 DATE: May 25, 2000

TC/TG/TRG TITLE: Smart Building Systems

DATE OF MEETING: February 8, 2000 LOCATION: Dallas

Membership status as of 4/00

Members Present	Appt	Members Absent	Appt	Ex-Officio Members Additional Attendance
Jim Braun	99-01	Rich Hackner	98-02	Hofu Wu
Todd Rossi	99-03	Patrick O'Neill (CM)	99-	Klaus Andersen
Les Norford	00-02	Mark Bailey (CM)	98-	Nemat Lotfi
Michael Kintner-Meyer	99-03	Tom Engbring (CM)	99-	Jonathan West

J. Carlos Haiad	00-04	Ron Nelson (CM)	98-	Gene Strehlow
Curt Klaassen	00-04	Barry Reardon (CM)	99-	Srinivas Katipamula
John House	99-03	Meli Sylianou (CM)	99-	Karl Strum
Steve Blanc	99-03	Michael Brandemuehl(CM)	99-	David Claridge
Mark Breuker	99-03			Luke Thompson
Barry Bridges	98-02			Scott Grefsheim
James Gartner	98-02			Bruce Westphal
John Seem	99-03			Peter Amstrong
George Kelly (CM)	99-			Maria Cinquino
Carol Lomonaco (CM)	00-			Max St-Denis
David Kahn (CM)	96-			Steve Bushby
Brian Kammers (CM)	96-			Osman Ahmed
Jim Winston (CM)	96-			Keith Temple

Philip Haves (CM)	00-			Robert Ries
Arthur Dexter (CM) (int'l member)	00-			Tom Watson
Charles Culp (CM)	00-			Pornsak Songkakul
John Mitchell (CM)	00-			John Phelan
Natascha Castro (CM)	99-			Ian McIntosh
Robert Old (CM)	00-			J.R. Anderson
				J.C. Visier
				Kim Barker
				Jeff Haberl
				Fred Buhl
				Hanjin Mao
				Agami Reddy
				Tom Webster

DISTRIBUTION:

ALL MEMBERS OF TC/TG/TRG

TAC CHAIMAN: Edward Gut

TAC SECTION HEAD: Byron Jones

ALL COMMITTEE LIASONS AS SHOWN ON TC/TG/TRG ROSTERS:

Program: Emil E. Friberg Manager Of Technical Services: Martin J. Weiland

Research: Sheila Hayter Manager Of Research: William W. Seaton

Standards: David Knebel Manager Of Standards: Claire B. Ramspeck

Journal: Chad Dorgan

TEGA: William Knight

Special Publications: Ramon Pons

ADDITIONAL DISTRIBUTION: Visitors listed above

ASHRAE TC ACTIVITIES SHEET

DATE: 22 May 2000

TC NO. TC4.11 TC TITLE: Smart Building Systems

CHAIR: J. Braun VICE CHAIR: L. Norford

TC Meeting Schedule

Location, past 12 mo.	Date	Location, next 12 mo.	Date

Seattle	6/22/99	Minneapolis	6/27/00
Dallas	2/8/00	Atlanta	1/30/01

TC Subcommittees

Subcommittee	Chair
Technology Development	T. Rossi
Communications and Integration	M. Kintner-Meyer
Testing and Evaluation	J. House
Research	G. Kelly
Program	C. Lomonaco
Standards	R. Hackner
Handbook	M. Bailey

Research Projects

1020-RP Demonstration of Fault Detection and Diagnostic Methods in a Real Building ((Final Report approved by TC 4.11 at Dallas Meeting, February 8, 2000)

1043-RP Fault Detection and Diagnostic Requirements and Evaluation Tools for Chillers

1139-RP Development and Comparison of On-Line Model Training Techniques for Model-Based FDD Methods Applied to Vapor Compression Equipment

Long Range Research Plan (as approved by TC 4.11 at the Seattle Annual Meeting)

Rank	Title	W/S Written ?	TC Approved ?	To RAC ?
1	Evaluation of Existing Fault Detection and Diagnostic Methods for Chillers	Yes (1st draft)	No	No
2	Integrated Control for Building Services[1]	Yes (3rd draft)	No	No
3	Resolving Discrepancies Between Multiple, Hierarchically-Related, Fault Detection and Diagnostic Systems	Yes (1st draft)	No	No
4	Prototyping and Field Testing of Utility-Consumer Information Services	Yes (1st draft)	No	No
5	Quantifying the Benefits of Fault Detection and Diagnostics of Roof Top Units	No[2]	No	No
6	Development of Fault Detection and Diagnostics for Sensor Failures	No[2]	No	No
7	Multi-Application Comparison of FDD Methods	No[2]	No	No

1. A work statement for Integrated Control for Building Services was approved by TC 4.11 and RAC and designated 1146-TRP, but the TRP was rejected by Technology Council. TC 4.11 has rewritten the work statement.
2. One-page project descriptions have been written.

Handbook Responsibilities - none

Standards Activities - none

Technical Papers from Sponsored Research - none

TC Sponsored Symposia (past 3 years, present, planned)

Title	**Date** **(Given or Planned)**
HVAC System Fault Detection And Diagnosis (Kelly)	Philadelphia, 1/97
Controlling Outdoor Air Ventilation for 62-1989 (Atkinson; TC 1.4 lead with TC4.11 as co-sponsor)	Toronto, 6/98
Fault Detection and Diagnostics - Learning from Building Operations (Ahmed; TC4.6 lead with TC4.11 as co-sponsor)	Chicago, 1/99
FDD Methods and Evaluation Techniques (Castro)	Chicago, 1/99
Demonstration of FDD Methods in Real Buildings (House)	Atlanta, 1/01
Recent Results from FDD Research (Norford)	Atlanta, 1/01

TC Sponsored Seminars (past 3 years, present, planned)

Title	**Date** **(Given or Planned)**
The Utility/Building Interface: Redefining an Old Relationship (Blanc)	Boston, 6/97
BACnet in the Real World (Bushby; TC 1.4 lead with SSPC 135 BACnet and TG4.SBS as co-sponsors)	Boston, 6/97
Automated Response To Real Time Pricing (Kammerud)	San Francisco, 1/98
The Delivery of New Energy Services under Electric Industry Deregulation (Nordham; TC4.11 lead with TC 1.4 as co-sponsor)	San Francisco, 1/98
Benefits of Integrating HVAC with Non-HVAC Systems (Newman; TC 1.4 lead with SSPC 135 BACnet and TC4.11 as co-sponsors)	San Francisco, 1/98
Impact of Electromagnetic Interference on Control Systems and Global Standards (Coogan; TC 1.4 lead with TC4.11 and TC 1.9 as co-sponsors)	San Francisco, 1/98
New Platforms and Gateways for Connecting into Building Management Systems (Phelan)	Toronto, 6/98
The Latest Control Communications Technologies (Gartner; TC 1.4 lead with TC4.11 as co-sponsor)	Toronto, 6/98
Customer Experience with Real-Time Pricing Electric Rates (Kintner-Meyer)	Chicago, 1/99

A Peek at a Real BACnet Building… GSA 450 Golden Gate BACnet Pilot Project (Blanc; TC4.11 lead, with TC1.4 co-sponsor)	Seattle, 6/99
State-of-the-Art Control Devices, Sensors, Motors and Intelligent Actuators (Atkinson; TC1.4 lead with TC1.2, SSPC 135 BACnet, and TC4.11 as co-sponsors)	Seattle, 6/99
Practical Experience Using DDC Systems for HVAC Commissioning and Continuing Evaluation (Bridges; TC1.4 lead with TC1.7, TC4.11 and TC9.9 as co-sponsors	Dallas, 2/00
Deregulation for Dummies (Haiad)	Dallas, 2/00
Evaluating the Benefits of Fault Detection and Diagnostics	Dallas, 2/00
Providing for the Most Important Part of a Smart Building Control System: People (Bridges)	Minneapolis, 6/00
Control Systems Integration, What's Happening with Practical Open-Architecture Solutions (TC 4.11 co-sponsor)	Minneapolis, 6/00
Evaluating Performance of FDD Products (Braun)	Atlanta, 1/01
FDD for Operations People, A Perspective on Using FDD Tools (Rossi)	Atlanta, 1/01
Strategies for Responding to Utility Curtailment and Price Induced Load Management (Breuker)	Atlanta, 1/01
BMA’s New Role in Testing the Interoperability fo BACnet Systems (SSPC 135	Atlanta, 1/01

lead)	
Adding New Life to Old System-Control Retrofit Case Studies (TC 1.4 lead)	Atlanta, 1/01
Wireless DDC Systems (TC 1.4, Bridges lead)	Atlanta, 1/01

TC Sponsored Forums (past 3 years, present, planned)

Title	**Date** **(Given or Planned)**
What Are The Priorities For On-Line HVAC Fault Detection And Diagnosis? (Haves)	Philadelphia, 1/97
Exactly What Do Smart Buildings and Control Systems Mean Today? (Newman and Kelly; TC 1.4 lead with TG4.SBS and TCs 1.5 and 4.6 as co-sponsors)	Boston, 6/97
Occupant Driven Interactive Building Control (Bridges; TG4.SBS lead with TC 1.4 as co-sponsor)	San Francisco, 1/98
Now That We Have the BACnet Standard Protocol, are DDC Programming Language and Application Standards Next? (Nesler; TC 1.4 lead with SPC 135 BACnet and TG4.SBS as co-sponsors)	San Francisco, 1/98
CAB and BACnet Similarities and Dissimilarities (Newman; TC 1.4 lead with SPC 135 BACnet and TC4.11 as co-sponsors)	Toronto, 6/98

How Can We Accomplish Multi-Vendor Interoperability in Existing Facilities? (Coogan; TC1.4 lead with SPC 135 BACnet and TC4.11 as co-sponsors)	Chicago, 1/99
What's ASHRAE's Role in Deregulation? (Blanc)	Seattle, 6/99
Measuring the Benefit of Fault Detection and Diagnostics (Breuker; TC4.11 lead with TC1.4 as co-sponsor)	Seattle, 6/99

TC Sponsored Public Sessions (past 3 years, present, planned)

Title	**Date (Given or Planned)**
Designing, Installing or Operating Engineers - Who Will Most Impact New Millenium Facilities? (Gartner; TC1.4 lead, with TC9.9 and TC4.11 as co-sponsors)	Chicago, 1/99

Journal Publications (past 3 years, present, planned)

Title	**When published**
None	

Minutes summary and activities sheet submitted by: Mark Breuker, TC4.11 Secretary

TC4.11 Minutes

Seattle: Tuesday, February 9, 2000

Roll Call, Introductions, Announcements, Minutes

Chairman Braun called the meeting to order at 3:30 p.m. A roll call showed that a quorum was present. In attendance at the meeting were Braun, Rossi, Norford, Kintner-Meyer, Haves, Dexter, Mitchell, House, Blanc, Breuker, Bridges, Gartner, and Seem for a total of 13 of 14 voting members. Braun distributed the minutes from the Seattle meeting, the agenda (the call-to-meeting letter and the agenda are in Appendix A), and the revised scope and organization of the committee. He then asked for introductions.

Carl Speich announced that any work statements that are approved by the committee are due to RAC by February 15.

Braun requested comments for minutes submitted from Seattle meeting. It was moved (House) and seconded (Rossi) to accept the minutes from the June 1999 meeting. The motion was approved unanimously.

Braun shared updates from the Technical Committee chairman's breakfast:

- Suggested we use the TC news section to publicize the activities of our committee and agreed to draft a summary of our activities.
- Justification is becoming more important for work statement now that Tech Council is also reviewing the work statements.
- Policy that we will now go into executive sessions when a contractor is selected for a research project.

Braun reviewed the scope of TC 4.11 and the new subcommittee structure (Appendix B) that is meant to be loosely organized around the project development process. Comments from Blanc and Lomonaco that we need more time for program at the end of the subcommittee meetings (at least 10 minutes). Agreed to leave this responsibility in the hands of the subcommittee chairs.

Technical Development Subcommittee (Rossi)

Fault Detection and Diagnostic Requirements and Evaluation Tools for Chillers (1043-RP).

Seems gave an update in the progress of project 1043, currently being performed by Purdue University. The majority of the work has been completed to the project monitoring subcommittee's satisfaction. It was moved (House) and seconded (Bridges) to grant no-cost extension to

Purdue University as follows: "TC 4.11 recommends that ASHRAE extend a no-cost extension to Purdue University for completion of 1043-RP until 8/31/2000, which was the date specified in their original proposal." Vote as passed 12 in favor, none opposed, 1 abstain.

Development and Comparison of On-Line Model Training Techniques for Model-Based FDD Methods Applied to Vapor Compression Equipment (1139-RP). Breuker presented an overview of the progress that has been made by the team at Drexel University on this project. Drexel provided a literature review, a list of techniques to be investigated, and a detailed project plan for gathering the necessary data for training and testing the techniques. The subcommittee approved the project plan presented by Drexel and provided some additional insight into the physical model approaches being considered. Questions were raised as to how this project related to extension to RP-1043. It was pointed out that the focus of this project was on the models and training techniques, not on the method of detecting and diagnosing faults.

Evaluation and Assessment of Fault Detection and Diagnostic Methods for Centrifugal Chillers – Phase II. This work statement describes a second-phase project intended to follow 1043-RP. In Phase 1, faults are being identified and experiments with faulty data are being conducted. Comments on the work statement included a recommendation that Phase 2 activity should focus on evaluation of FDD methods that bidders should identify in their proposals. Srinivas modified the work statement based on comments in Seattle. After much discussion it was decided to vote in Minneapolis after the 1043 project was completed and some additional insight into the potential results for 1139 were better understood. Srinivas agreed to modify based on comments and have the work statement ready for Minneapolis.

Development of FDD for Sensor Failures. Dexter agreed to move this work statement forward for the meeting in Minneapolis.

Rossi asked for ideas for new work statement and requested that one-pagers be submitted in Minneapolis for review. Kintner-Meyer suggested focusing on intelligent sensors and embedded technology issues.

Steve Blanc shared information on a workshop that PG&E is sponsoring on May 16 on FDD run by Ryan Strouppe.

The minutes of the subcommittee meeting are in Appendix C.

Communications and Integration Subcommittee (Kintner-Meyer)

No current research that is part of this subcommittee, so most of the discussion centered on a few proposed work statements.

Prototyping and Testing of Utility/Customer Information Services. This work statement is intended to implement communications services selected from those identified in 1011-RP. Kintner-Meyer stated that there will be two phases: a lab test with computers as part of Phase 1 and a field test in Phase 2. Kintner-Meyer sought the input from SSPC 135, the BACnet committee. Steve Bushby circulated the work statement to the BACnet committee, but it was not discussed. TC1.4 was asked to co-sponsor the work statement, but declined because they felt like it was not in their research scope. Kintner-Meyer agreed to present to the BACnet committee for buy-in before next meeting. Expected to vote on the work

statement in Minneapolis.

Resolving Discrepancies Between Multiple, Hierarchically-Related, FDD Systems.
In Seattle, Brambley agreed to scale back to a literature review and scoping study, to further define the problem. In Dallas, no significant progress had been made on the work statement. After some discussion, it was decided to put this work statement on hold until FDD systems had achieved some more significant development and market penetration, providing additional justification for this work.

Osman Ahmed and Kintner-Meyer discussed the need to bring in web-based technologies as part of this committee's scope. They are preparing a bullet sheet for discussion at the meeting in Minneapolis.

The minutes of the subcommittee meeting are in Appendix D.

Testing and Evaluation Subcommittee (House)

Demonstration of Fault Detection and Diagnostic Methods in a Real Building (1020-RP). House reported that the PMS held a meeting on Saturday to review the final report from contractors at MIT and Loughborough University. Norford gave a 20-minute overview of methodology and the results of the project. The project compared physical models and expert rules for their FDD sensitivity with faults introduced in controlled and blind tests. Both methods appeared to have some difficulty diagnosing faults, especially in the blind tests. The PMS recommended the project be approved subject to the revision of the tables of results. Haiad stressed the importance of having the severity of the faults documented in the tables. Haves questioned the final conclusions from the work. Kelly gave the methods an overall C+, but gave the contractors an A+ for the work. Many stated that this project shows that the methods were are not ready for commercialization. A motion to approve the final report for RP-1020 subject to the changes in the table of results was given by House with a seconded by Mitchell. The vote recorded 12 in favor, 0 against, 1 abstain.

Integrated Control for Building Services (1113-TRP). In Seattle, House reported that TC 4.11 recommended a contractor at the Chicago meeting. RAC approved the recommendation but Technology Council turned it down, not seeing a need for the work and in general not favoring surveys. Comments were provided at the subcommittee meeting for a substantially revised work statement. In Dallas, House mentioned possible BOMA support of the work statement. He is planning to revisit the work statement and provide in a possible email ballot.

Quantifying the benefits of FDD. Rossi presented this potential idea for a work statement to the committee. Committee provided feedback that this is still an important problem and to focus in the easily quantified benefits such as energy and maintenance and stay away from issues harder to quantify such as productivity. Rossi mentioned possible co-sponsor from DOE. Rossi to take the lead in developing a draft work statement for Minneapolis.

Norford agreed to develop a follow-up work statement for RP-1020 for discussion in Minneapolis.

The minutes of the subcommittee meeting are in Appendix E.

Research Subcommittee (Kelly)

Kelly presented the research plan for the coming year, included in Appendix G and summarized as follows:

Project	Contributors	Status
1. Evaluation of Existing Fault Detection and Diagnostic Methods for Chillers	Srinivas Katipamula	2st draft of work statement
2. Integrated Control for Building Services	John House R. Kammerud J. Mitchell	TRP Rejected by Tech. Council, TC will rewrite WS
3. Resolving Discrepancies Between Multiple, Hierarchically-Related, Fault Detection and Diagnostic Systems	Todd Rossi Mike Brambly	Put on back burner pending further FDD research
4. Prototyping and Field Testing of Utility - Consumer Information Services	M. Kintner-Meyer Marty Burns Chuck McParland	2st draft of work statement

5. Quantifying the Benefits of Fault Detection and Diagnostics	Todd Rossi Mark Breuker Jim Braun	one page description
6. Development of Fault Detection and Diagnostics for Sensor Failures	Arthur Dexter	one page description
7. Multi-Application Comparison of FDD Methods	John House	one page description

Kelly pointed out the need to evaluate and extend RP-1043 for Minneapolis and push for a possible mail ballot on the integrated building controls work statement. He also noted the moving of the hierarchical FDD to the back burner and the need to push for a decision on Kintner-Meyer's work statement regarding prototyping and testing of the utility-customer information services. We will need a one-pager on the intelligent sensors topic and a new research plan in Minneapolis

Program Subcommittee (Lomonaco)

Lomonaco reviewed the program for the Dallas meeting and encouraged participation in the FDD seminar on Wednesday morning.

Lomonaco presented plans for programs at upcoming meetings. Braun pointed out the need for additional seminars and symposiums and to move these to the top of our program priorities.

It was moved (Lomonaco) and seconded (Braun) to approve the program for Minneapolis as presented by Lomonaco. The motion passed by unanimous voice vote. Programs as subsequently approved by ASHRAE are tabulated at the beginning of these minutes.

Lomonaco also noted that we need to have a unified approach to submit programs to Mary McGee. Forms should be sent in through Chairman Braun. Lomonaco also noted that there are many paper submitted to ASHRAE without a symposium in mind. These may provide additional speakers for symposiums and seminars. Contact Mary McGee at ASHRAE for this data.

ASHRAE Web Support

Blanc noted that ASHRAE should be providing web support and hosting for the TC web sites. Byron Jones agreed to provide the comments to TAC. It was moved (Bridged), seconded (Mitchell) to have Chairman Braun write a letter requesting that ASHRAE provide web hosting services to the technical committees and request a date and itemized cost for this effort. Vote was unanimous in favor.

Roster for Januay 2000 – January 2001

Braun noted that Dexter and Haves will be rolling off and Haiad and Klassen would become voting members. Braun requested that people make requests to him if they would like to become voting members

Old business

None

New business

Informal discussion about putting together a handbook chapter on smart building systems. Braun to put together an outline of what the chapter might look like for discussion in Minneapolis. Gartner noted that TC 1.4 is updating their chapter and to make sure we coordinate with Monica Amalfitano. Brambley also indicated that we should coordinate with TC1.5, Mike Pouchak is on the handbook committee – mpouchak@HBC.honeywell.com. To get into the next cycle (2003), need a draft by 2001. General consensus that it belonged in the applications volume.

Discussion led by Haiad about the need for coordination with TC 1.5. Brambley added that this might be a place to add some handbook items without having to put together a whole chapter. Kelly noted that we need continued brainstorming about the topics that will take on in the future.

Adjournment

It was moved (Rossi), seconded (Norford), and unanimously voted to adjourn at 6 p.m.

Appendices

A. Call to Meeting and Agenda
B. Scope and Organization
C. Technology Development Subcommittee Report

D. Communications and Integration Subcommittee Report (not available yet)
E. Testing and Evaluation Subcommittee Report
F. Research Plan and Activities
G. List of Subcommittee Attendees
H. Program Subcommittee Report – not provided by subcommittee chair

Appendix A.

Call to Meeting and Agenda

ASHRAE American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

1791 Tullie Circle, NE, Atlanta, Georgia 30329-2305 404-636-8400 | Fax 404-321-5478

Reply to: Jim Braun

Ray W. Herrick Labs

Purdue University

W. Lafayette, IN 47907

(jbraun@ecn.purdue.edu)

January 17, 2000

Dear TC 4.11 Member, International Member, or Corresponding Member,

The **TC** on Smart Building Systems and its subcommittees will meet in Dallas according to the following schedule:

TC 4.11 Technology Development Sunday (2/06) 3:00-4:00p Dallas A3 (CC/1)

TC 4.11 Communication & Integration Sunday (2/06) 4:00-5:00p Dallas A3

TC 4.11 Testing & Evaluation Sunday (2/06) 5:00-6:00p Dallas A3

TC 4.11 Smart Building Systems Tuesday (2/08) 3:30-6:00p State 2 (CC/3)

TC 4.11 PMS 1020-RP Saturday (2/05) 5:00-6:00p Pearl 2 (Adams)

TC 4.11 PMS 1139-RP (OVH) Sunday (2/06) 6:45-8:00p Dallas A3

TC 4.11 PMS 1043 RP (5/5) Monday (2/07) 2:00-3:00p Majestic 9 (H/37)

The TC is the sponsor or co-sponsor for the following sessions in Dallas:

Seminar 9: Practical Experience Using DDC Systems for HVAC Commissioning and Continuing Evaluation, Sunday, February 6, 2000, 10:15 AM – 12:15 PM

Seminar 22: Deregulation for Dummies, Monday, February 7, 2000, 10:15 AM – 12:15 PM

Seminar 46: Evaluating the Benefits of Fault Detection and Diagnostics, Wednesday, February 9, 2000, 10:15 AM – 12:15 PM

(See the ASHRAE Program Booklet for session locations and to confirm the times.)

Attached is a draft agenda for the full TC 4.11 committee meeting in Dallas. I hope to see you all there.

Jim Braun

Chairman, TC 4.11

ASHRAE TC 4.11

Smart Building Systems

2000 Winter Meeting, Dallas

DRAFT AGENDA

Location: State 2 (CC/3)

Date: Tuesday, February 8, 2000

Time: 3:30 - 6:00 p.m.

1. Roll call and introductions

2. Approval of Minutes from Seattle

3. Announcements
4. Review of Subcommittee Structure and Scopes

5. Technology Development Subcommittee Report (Todd Rossi)

1043-RP, Fault Detection and Diagnostic (FDD) Requirements and Evaluation Tools

for Chillers (John Seem)

1139-RP, Development and Comparison of On-Line Model Training Techniques for Model-Based FDD Methods Applied to Vapor Compression Equipment (Mark Breuker)

Draft Work Statements

Program plans

Other activities

6. Communications and Integration Subcommittee Report (Michael Kintner-Meyer)

Draft Work Statements

Program plans

Other activities

7. Testing and Evaluation Subcommittee Report (John House)

1020-RP, Demonstration of Fault Detection and Diagnostic Methods in a Real

Building (John House)

Draft Work Statements

Program plans

Other activities

8. Research Subcommittee Report (George Kelly)

New Work Statements

Research Plan

9. Program Subcommittee Report (Carol Lomonaco)

Plans for Minneapolis (6/2000)

Plans for Atlanta (1/2001)

Plans for future meetings

10. TC 4.11 Website (Rich Hackner)

11. TC 4.11 2000-2001 Roster

12. Additional old business

13. Additional new business

14. Adjournment

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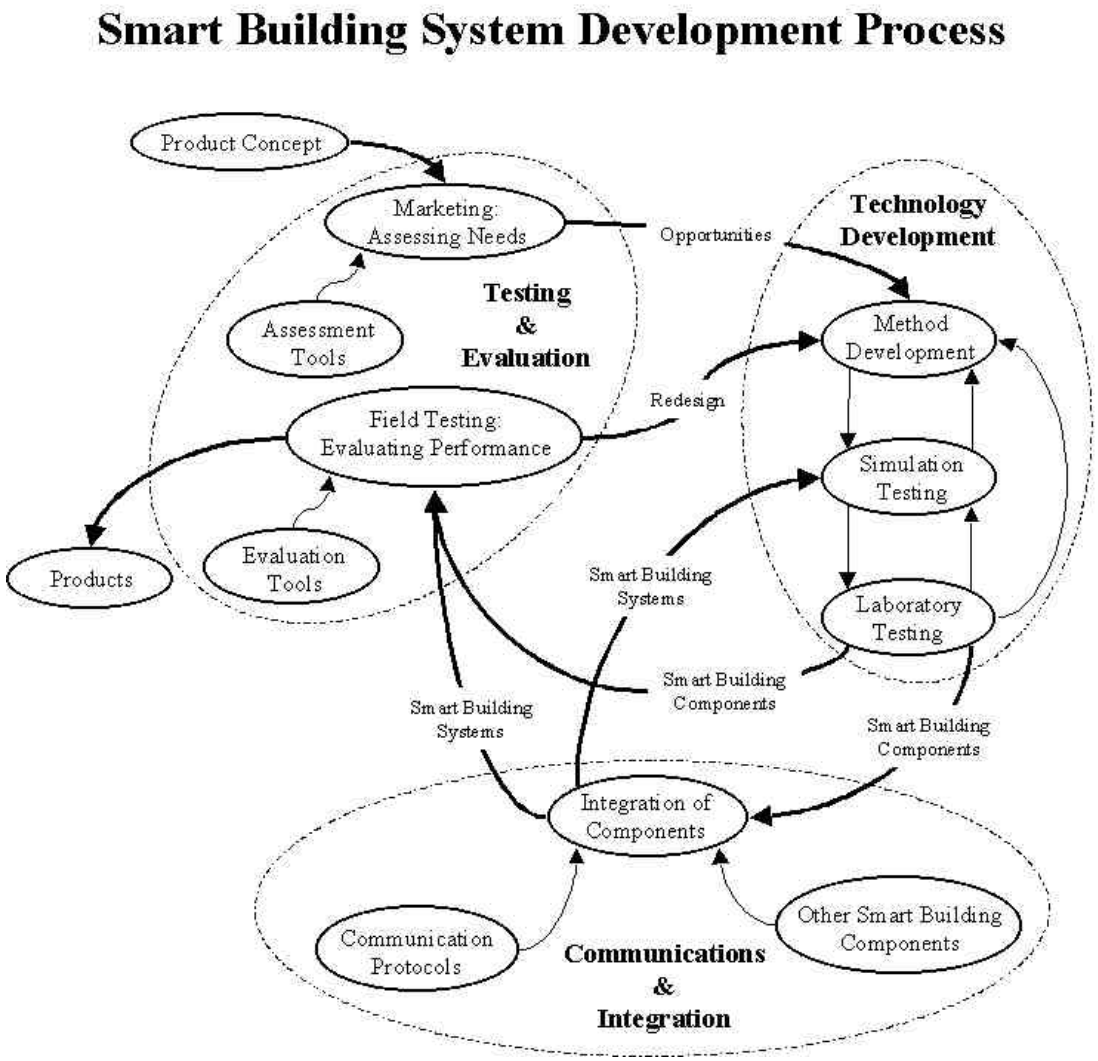
Appendix B.

TC 4.11, Smart Building Systems Scope and Organization

July 1, 1999

Overall Committee Scope

The Technical Committee on Smart Building Systems (SBS), TC 4.11, is concerned with the development and evaluation of technologies that could enable the widespread application of smart building systems. "Smart" buildings should take advantage of automation, communications, and data analysis technologies in order to operate in the most cost-effective manner. This implies integration of building services such as HVAC, fire, security, and transportation; the automation of many of the operation and maintenance functions traditionally performed by humans; and the interaction with outside service providers such as utilities, energy providers, and aggregators. Currently, three subcommittees form the backbone of the TC's activities: technology development, communications and integration, and testing and evaluation. The scope and activities of these subcommittees loosely follow the product development process as depicted in following flow chart and as defined in the following sections.



Technology Development Subcommittee

The Technology Development Subcommittee is concerned with research issues associated with the development of emerging smart building technologies such as (but not restricted to) automated commissioning, performance monitoring, fault detection and diagnosis, optimal maintenance scheduling, and optimal control. The primary outcome of research endorsed by this subcommittee is expected to data and models that enable development of the technologies and comprehensive methods that are the basis of the technologies. An integral part of the development process is

simulation and laboratory testing. Proposed designs must be tested and modified prior to field evaluation. Specific research topics that are ongoing or planned under this subcommittee are:

- 1043-RP Fault Detection and Diagnostic (FDD) Requirements and Evaluation Tools for Chillers
- 1139-RP Development and Comparison of On-Line Model Training Techniques for Model-Based FDD Methods Applied to Vapor Compression Equipment
- Fault Detection and Diagnostic Methods for Chillers

- Development of Fault Detection and Diagnostics for Sensor Failures

Communications and Integration Subcommittee

The Communications and Integration Subcommittee is concerned with research issues associated with enabling the seamless interaction of smart building components and services. An important aspect of this work is to identify the information that is necessary to support smart building technologies, and to identify the requirements of communication protocols to support the exchange of this information between different building services, between buildings and utilities, between multiple buildings, with outside service providers, etc. Specific research topics that are ongoing or planned under this subcommittee are:

- 1011-RP Utility/EMCS Communication Protocol Requirements (Completed: 6/99)

- Resolving Discrepancies Between Multiple, Hierarchically-Related, Fault Detection and Diagnostic (FDD) Systems
- Prototyping and Field Testing of ASHRAE's Utility Consumer Interface Models (UCIM)

Testing and Evaluation Subcommittee

The Testing and Evaluation Subcommittee is concerned with research issues associated with assessing the benefits (market potential) and performance of smart building technologies. Research endorsed by this subcommittee is expected to result in data, metrics, methods, and tools/standards/guidelines for quantifying smart building system benefits and performance in a standardized manner, as well as findings from the actual application of these metrics, methods and tools. Specific research topics that are ongoing or planned under this subcommittee are:

- 1020-RP Demonstration of Fault Detection and Diagnostic Methods in a Real Building

- Integrated Control for Building Services

- Quantifying the Benefits of HVAC Equipment Monitoring and Fault Detection

- Multi-Application Comparison of Fault Detection and Diagnostic Methods

Appendix C.

TC4.11 Technology Development Subcommittee Meeting

Minutes

Dallas: February 6, 2000 3:00-4:00 p.m.

1. Todd Rossi reviewed scope of work of the subcommittee and briefly reviewed ongoing projects/work statements/research ideas.

- *Development and Evaluation of FDD Methods for Chillers – Phase II*

- *Development of FDD for Sensor Failures* – Arthur Dexter is the lead and outlined some of the primary areas of research that is needed. Phil Haves will contribute and present a draft work statement at the Minneapolis Meeting.

1. Development and Evaluation of FDD Methods for Chillers – Phase II

- Jim Braun gave a brief update. Phase I nearly completed … dynamic models are not complete but should be by Minneapolis.

- Srinivas Katipamula reviewed the Phase II work statement. Some changes have been made to emphasize that methods tested must be cost effective. Also, a more complete description of Phase I is included.
- Comments
- Rossi: Objectives still need some clarification between Objectives 1 and 2. Still unclear where methods would come from … developed or existing. Suggestion was to change the wordings of Objectives 1 and 2:

    1. Develop procedures for evaluating and comparing **existing** FDD methods …
    2. Assess the performance of the **selected** FDD methods …

- Rossi: Should we require some type of letter from individuals providing methods indicating they will work with the contractor to implement the method.
- Dexter: How do we make sure that the proper methods are considered and not just those of colleagues close to the bidder?
- Ahmed: Bidders must clearly justify selection of methods.

- Dexter: Why then do we need to have an objective to select methods.
- Mitchell: Seems to be a lot of overlap between this work and the work of 1139-RP?
- Katipamula: 1139-RP is basically model/on-line training method development and this work is testing existing methods.
- Rossi: Maybe work statement should mention that bidders should be aware of 1139-RP work.
- Mitchell: Does this create problems because 1139-RP is ongoing and not public information.
- Dexter: Are we talking about fault detection and diagnosis? The models from 1139-RP would only allow fault detection since they are for normal operation.
- Haves: 1139-RP … thresholds for detection linked to how well you train models.
- Haves: Research budget tight at this time for this type of research … may want to wait until 1139-RP is completed.
- Rossi: Should we wait on this work statement for the time being. Reasons: 1143-RP not quite finished and 1139-RP is also ongoing. These projects (at least 1143-RP) should be completed so we can evaluate that work before going on.
- Mitchell: Background should have a roadmap of how all this FDD work fits together. (i.e., 1043-RP, 1139-RP, Phase II and Phase III)
- Rossi: Remove reference to and tasks under Phase 3. This will be included in Background/roadmap.

- Kelly: Describe how proposals be evaluated.
- Haves: Make explicit the current state-of-the-art and what is the anticipated state-of-the-art coming out.
- Ahmed: How do you establish the benchmark for how well a chiller is working or should be working?

Summary: Evaluated WS and provided numerous comments to be considered/incorporated. Want to wait until 1043-RP is completed before moving forward.

1. New WS as a follow-up to 1020-RP … maybe more appropriate for Testing and Evaluation Subcommittee.

- One person would conduct tests of various FDD methods submitted by individuals. This takes the operator out of the loop.
- Iowa Energy Center would produce more data (normal and faulty).
- Should there be some survey of what are the most important problems that building operators face?
- Norford, House and Klaassen will take lead on development of WS and will have something for Minneapolis.

1. Other ideas for new work statements.
2. Ahmed: MEMS and other sensors, intelligent agents, embedded technologies, Internet, etc. … How can these technologies be applied to buildings of the future? We should look more at the system level rather than just at the component level. Action item for next meeting: List of emerging technologies and possible ways they could be applied to buildings.

Program:

Light on program for Minneapolis. Maybe a forum on sensor technology. Perhaps another seminar on "Practical Experiences with and Needs for FDD …", but this time from an operations point of view.

PG&E is sponsoring a workshop in June on diagnostics.

Submitted by John House

Appendix D.

TC4.11 Communications and Integration Subcommittee Meeting

Minutes

Seattle: February 6, 2000 4:00-5:00 p.m.

Chairperson: Michael Kintner-Meyer

Waiting for the minutes from Kintner-Meyer.

Appendix E.

TC4.11 Testing and Evaluation Subcommittee Meeting

Minutes

Seattle: June 20, 1999 5:00-6:00 p.m.

Notes by: Todd Rossi

John House's review

- 1020-RP review. Final report submitted. Finalization expected at this meeting. Follow-on work is being identified. Pick up on the follow up work in Minneapolis.
- Integrated Control of Building Services. Tech counsel did not approve.
- Quantifying Benefits of FDD methods. Work on this work statement and discuss at the next meeting.

- Need to look for other application areas.

John House reviewed the work statement on Integrated Control of Building Services.

- John received many comments/feedback since the last meeting.
- Steve Blanc: Work statement needs specific subjects to work around. It is too nebulous.
- John House discussed partnering with BOMA. Help develop survey and distribute on their letterhead. Better result than one contractor. John found interest at BOMA. Would need money to pursue. Amount unknown. BOMA has a white paper on the topic. Carlos: Pass BOMA cost through contractor.
- John asked for consensus to pursue this work statement. George Kelly and Carol Lomaneco supported the need for this work. Carlos supports project and BOMA's involvement.
- John asked: Pay BOMA with money or sharing data. Bill Seaton not excited about sharing data with BOMA for independent analysis.
- Barry Bridges and Steve Blanc discussed what happens if only a few survey responses are returned. Is it representative of the larger group. Current expectation is to get around 100 buildings. Medium is flexible (e.g. phone, field survey).
- Concern about not doing work with grad students. The money was raised to $90K and now the discussion is around $150K. Barry suggested breaking the project into smaller steps to move forward. John is concerned about transferring between contractors. How about co-funding?
- Need information from 100 buildings + other stakeholders. How does this fit in.
- Barry: Replace "buildings" with "facilities" or large complexes. How to sample the buildings to get statistically significant sampling? Lower cost to get less detail or don't worry about statistical significance. Carlos: Pick a type of building (e.g. office).
- John concluded that there is still interest to pursue. John will pursue interaction with BOMA and specify their needs/interest better.
- There is much concern about how long this work statement has been kicking around.

Quantifying benefits of FDD

- Many agree this is important to continue to pursue.
- Separate benefits of FDD with benefits of fixing problem

- Performance indices: costs, complaints, productivity
- Jim Braun: Do the easy stuff first.
- Overlaps benefits of commissioning where this is recognized as a problem.
- Do commissioning or use tools to find problems?
- Help to work on work statement: Ian Mackintosh , Curt.

Multi-application of FDD methods

- John House reported no progress.
- Work statement is still on the table.

Program

- Les Norford offered to chair a FDD symposium.
- BACnet certification. Check with Steve to see if there is a symposium on this topic.

Appendix F.

TC 4.11 Smart Building Systems

Research Plan and Activities

July 1999

Research Objectives: The long-term goal of TC 4.11 is to conduct research on topics that will lead to the development and application of "smart" building systems. "Smart" buildings of the future will take advantage of automation, communications, and data analysis technologies in order to operate in the most cost-effective manner. A smart building would most likely have fully integrated control of building services such as HVAC, fire, security, and transportation. Integrated systems would reduce initial costs and could be "supervised" so as to meet the primary objectives of comfort, safety, and performance at minimum operating cost. In addition, the integration of the hardware and software for operation and monitoring of equipment would lead to reductions in support staff needs and improved equipment reliability. Further cost reductions and reliability improvements would be possible through the integration of automated techniques for detection and diagnosis of equipment faults. Ultimately, "smart" building systems could facilitate the use of "remote" support staff that operates, monitors, and maintains a number of different buildings from a centralized location. At this higher level, a smart building might communicate and inter-operate with other smart buildings for the purpose of load aggregation and centralized control and with outside service providers, such as utilities, energy providers, aggregators, and newly developing companies providing fault detection, automated commissioning, optimization, and other innovative services. In addition to the savings in operating costs associated with "smart" buildings, other benefits include energy conservation and enhanced occupant safety and comfort.

Several developments are needed before "smart" building systems become a reality. These include demonstrating the benefits of possible features (e.g., system integration, fault detection and diagnostics, load aggregation); developing and demonstrating the communication protocols necessary for different systems and players to communicate (including communications between building systems and utilities); and developing, demonstrating, and evaluating systems for performance monitoring, fault detection, and fault diagnosis of typical equipment and systems.

Current TC 4.11 research includes projects in many of these areas. The evaluation of communication protocol requirements between utilities and energy management systems is being addressed in 1011-RP. Fault detection and diagnostics (FDD) is being considered for a number of different HVAC applications. Demonstration of the performance and benefits of current FDD approaches for air handling systems is being performed as part of 1020-RP. The identification of important faults and their impacts on performance for chillers is being determined in 1043-RP, while the development of on-line training techniques for model-based FDD methods is being carried out in 1139-RP for vapor compression equipment.

TC 4.11, Smart Building Systems

Research Plan and Activities

June 1999

Current Research Projects

1011-RP - Utility/EMCS Communication Protocol Requirements (Final Report approved by

TC 4.11 at Seattle Annual Meeting on 6/22/99.)

1020-RP - Demonstration of Fault Detection and Diagnostic Methods in Real Buildings

1043-RP - Fault Detection & Diagnostic Requirements & Evaluation Tools for Chillers

1139-RP - Development and Comparison of On-line Model Training Techniques for Model-Based FDD Methods Applied to Vapor Compression Equipment

1999-2000 Research Plan

Project	Contributors	Status
1. Evaluation of Existing Fault Detection and Diagnostic Methods for Chillers	Srinivas Katipamula	2nd draft of work statement
2. Integrated Control for Building Services	John House R. Kammerud J. Mitchell	TRP Rejected by Tech. Council, TC will rewrite WS
3. Resolving Discrepancies Between Multiple, Hierarchically-Related, Fault Detection and Diagnostic Systems	Todd Rossi Mike Brambly	Rewrite draft WS to be a "scoping study"
4. Prototyping and Field Testing of Utility - Consumer Information Services	M. Kintner-Meyer Marty Burns Chuck McParland	2nd draft of work statement
5. Quantifying the Benefits of Fault Detection and Diagnostics	Todd Rossi Mark Breuker Jim Braun	One page description
6. Development of Fault Detection and Diagnostics for Sensor Failures	Arthur Dexter	one page description

7. Multi-Application Comparison of FDD Methods	John House	one page description

TC 4.11, Smart Building Systems

Research Project Description

Priority 1

Project Title: Evaluation of Existing Fault Detection and Diagnostic Methods for Chillers

Summary: In 1043-RP, the important faults to be considered and the appropriate sensors were identified. In addition, a physical model for simulating chiller behavior was developed to evaluate the effectiveness of the various FDD methods in identifying different faults. In this project, different FDD methods will be implemented and evaluated through the use of simulation. Procedures to evaluate and compare the various FDD methods will be developed. Promising FDD methods will be selected and recommended for future laboratory and field testing.

Objective: Develop procedures for evaluating and comparing different FDD methods for chillers, and assess the performance of the methods through simulation.

Benefits: Automated FDD applied to chillers used in air conditioning of commercial buildings has the potential to reduce energy and maintenance costs and improve comfort and reliability. Although current control systems typically monitor many variables, this information is not used for diagnosing faults. At best, these systems incorporate automatic shutdown procedures that guard against catastrophic failures when measurements are extremely out of range.

Estimated Cost: $90,000

Estimated Duration: 18 months

Methods of Publishing Results

1. Detailed Reports
2. Technical Paper(s)

Potential Cosponsors:

1. chiller manufacturers
2. chiller service providers

TC 4.11, Smart Building Systems

Research Project Description

Priority 2

Project Title: Integrated Control for Building Services

Summary: The integration of the control of multiple building services, such as HVAC, fire, security, and transportation, offers building owners and operators many benefits and some possible problems. Unfortunately there has been no systematic research to evaluate and document the pros and cons of integration, nor to examine the different methods by which it may be achieved. This study will examine different levels of integration in commercial office buildings, including no integration, the use of a single network by different building systems (token integration), full integration using a building management system from a single vendor, and different vendor supplied building systems using a common communication protocol, such as BACnet. The benefits and problems associated with each approach will be carefully documented. In addition, various performance measures will be developed to compare the safety, reliability, comfort, cost, energy consumption, ease of use, maintenance requirements, etc. of the different approaches.

Objectives:

1. To examine different approaches to the integration of building services in a variety of commercial office buildings.
2. To evaluate and document the pros and cons associated with each approach.
3. To develop performance measures that can be used by building designers, owners, and operators for comparing different levels of integration and for selecting the best approach for a given application.
4. To develop recommendations for future research in this area.

Benefits: This research will provide valuable information on the benefits and problems associated with the integration of building services. The development of performance measures for comparing different approaches should significantly improve the decision making process for building designers, owners, and operators. In addition, this work is likely to lead to the future development of ASHRAE Guidelines on evaluating and choosing the best approach to integrating building services in different applications.

Estimated Cost: $50,000

Estimated Duration: 10 months

Methods of Publishing Research Results:

1. Detailed Reports
2. Technical Paper(s)

TC 4.11, Smart Building Systems

Research Project Description

Priority 3

Project Title: Resolving Discrepancies Between Multiple, Hierarchically-Related, Fault Detection and Diagnostic Systems

Summary: A variety of different fault detection and diagnostic (FDD) methods have been studied (by IEA Annex 25 and others) and applied to HVAC systems using either simulation or laboratory test rigs. It was found that each of the methods appears to have different strengths and weaknesses. Thus, future FDD systems installed in actual buildings are likely to employ a number of different FDD methods on the same HVAC subsystem, different HVAC subsystems, and at different levels within a building's energy management and control system (EMCS). How the results from all these different FDD applications are coordinated, integrated, evaluated, and how conflicts are resolved and information presented to the operator in an intelligent manner needs to be addressed.

Objectives:

1. Select several promising methods for performing FDD on selective HVAC subsystems
2. Examine different approaches for applying these multiple methods to the same and different subsystems and at different control levels
3. Examine different approaches for coordinating, integrating, evaluating, and presenting the resulting information to the building operator.
4. Evaluate and document the benefits and problems associated with each approach to FDD conflict resolution and recommend one or more preferred distributed/hierarchal FDD architectures for use in HVAC applications.

Benefits: A better understanding of the different approaches for integrating FDD methods in a distributed and hierarchical manner will accelerate the development and implementation of FDD systems in buildings. This in turn should lead to improved HVAC performance, reduced energy

consumption, and lower operating and maintenance costs.

Estimated Cost: $75,000

Estimated Duration: 12 months

Methods of Publishing Research Results:

1. Detailed Reports
2. Technical Paper(s)

TC 4.11, Smart Building Systems

Research Project Description

Priority 4

Project Title : Prototyping and Field Testing of Utility-Consumer Information Services

Summary: ASHRAE is currently funding the research project titled: "Utility/Energy Management and Control System (EMCS) Communication Protocol Requirements" (RP1011). The objectives of RP1011 are: 1) to identify potential new information services that electricity suppliers are likely to offer to their customers and 2) to determine the communication requirements to establish the service provider/customer communication link. To meet these objectives, several information services were defined and their data and communication requirements were discussed and documented in RP1011. For each information service, an object oriented data model is being developed that succinctly conveys the necessary information between the communicating parties. The set of data models is called *Utility Consumer Interface Models (UCIM).* As a natural extension of RP1011, ASHRAE intends to prototype and test the UCIMs and the communication between a utility partner and end-users under real world conditions

Objectives:. To prototype and test the UCIMs and utility/end-user communication, a phased implementation and testing approach is proposed. In Phase I, a prototype of selected information services will be developed and implemented for one commercial/industrial and one residential application. In phase II, small field trials with 5-20 participants consisting of residential and commercial/industrial customers will be conducted. The objective of the field trials is to gain experience in the implementation into a broad scale of customers EMCS systems and to study the performance of UCIM communications in diverse EMCS and SCADA environments. Phase II requires utility participation to deploy the prototype at several customers' sites.

Benefits: This demonstration will benefit ASHRAE by facilitating the clear definition of responsibilities for communications between customer owned

automation systems utilizing BACnet and external parties such as utilities, energy service providers, and other third parties. As such it will explore opportunities for utilizing the Internet and information technology in an environment of distributed computation and responsibility.

Estimated Costs: Phase I: ASHRAE: $140,000

Phase II: ASHRAE: $25,000

Utility partners: $300,000

Estimated Duration: Phase I – 12 months

Phase II – 12 months

Potential cosponsors

SSPC 135

TC 4.11, Smart Building Systems

Research Project Description

Priority 5

Project Title: Quantifying the Benefits of HVAC Equipment Monitoring and Fault Detection

Summary: The most significant barrier to market acceptance of HVAC equipment monitoring and FDD tools is the inability to quantify the benefits to a customer. Benefits can be either increased reliability or lower costs, including equipment, energy, and service. Costs are quantified monetarily, but increased reliability is more difficult, but may, for example, be the percent of occupied time at set point. This project will attempt to quantify the benefits of HVAC Equipment Monitoring and Fault Detection.

Objective: The objective of this research is to develop a tool (or tools) for quantifying the benefits of monitoring and FDD for specific customer. The project's scope may be adjusted in the following ways:

1. Discuss "Tools" versus more basic "Techniques".
2. Cover general techniques for all HVAC equipment or limit to particular types, such as chillers in central plants or rooftop units.
3. The problem can be more specifically defined. The tool could use a model-based approach to calculate costs with and with out monitoring and

FDD. The models may be typical for a class of building or application or learned for a particular site. The HVAC costs depend on the weather, comfort control strategy, and state of faults. This tool needs a HVAC equipment model with faults, building model, load profile, service profile, and weather information.

Benefits: This research will help overcome the most significant barrier to market acceptance and ultimately research funding for HVAC equipment monitoring and FDD, which may lead to significant increases in reliability and lower operating costs. Impacts include:

1. Increased up time because hard faults are detected faster and performance degradations can be anticipated by observing the trend as they develop.
2. Equipment or first costs will increase because of the introduction of the monitoring equipment.
3. Energy and service cost may increase or decrease because more up time and more awareness of service needs may use more energy and service. Costs may also increase soon after monitoring and FDD is implemented and then decrease after pent up demand for more and better service is satisfied.

Estimated Cost: $90,000

Estimated Duration: 12 months

Methods of Publishing Research Results:

1. Detailed Reports
2. Technical Paper(s)

TC 4.11, Smart Building Systems

Research Project Description

Priority 6

Project Title: Development of Fault Detection and Diagnostics for Sensor Failures

Summary: The purpose of this research is to develop Fault Detection Diagnostics (FDD) methods for detecting failed sensors of the type that are typically used in HVAC systems, including: temperature sensors, electricity sensors and flow sensors. Examples of known FDD sensors techniques include: high-low limit comparisons, model comparisons, sensor redundancy, and analytical redundancy. This work would be beneficial to implementing Fault Detection Diagnostics that are dependent on the accurate data from a suite of sensors.

Objectives: This objectives of this research include: (1) a thorough literature search into the current methods that are used to detect sensor failures of the type that typically used in HVAC systems, (2) the development of a suite of FDD procedures for HVAC sensors, and (3) the testing and verification of the developed FDD procedures on specially prepared data from sensors that contain known faults.

Benefits: The project will benefit ASHRAE membership as well as the general public as follows:

1. Assist ASHRAE to develop methods to detect fault diagnostics in sensors.
1. Help equipment suppliers as an aid for incorporating FDD techniques into equipment.
2. Encourage the documentation of such methods.
3. Allow ASHRAE to develop more effective training programs for teaching engineers and architects how to apply FDD methods to sensors.
4. Improving energy efficiency by providing ASHRAE members with improved methods for sensor FDD.

Estimated Cost: $75,000

Estimated Duration: 18 months

Methods of Publishing Research Results:

1. Detailed Reports
2. Technical Paper(s)

TC 4.11, Smart Building Systems

Research Project Description

Priority 7

Project Title: Multi-Application Comparison of FDD Methods

Summary: One of the challenges of developing a fault detection and diagnostic (FDD) method is the question of how the method should be tested and evaluated. Simulation testing is necessary and beneficial; however, by itself, simulation testing can not adequately evaluate the performance of an FDD method. A standardized testing procedure and performance indices that utilized accepted simulation data sets as well as laboratory/real building data sets would provide developers of FDD methods with a common approach for assessing FDD method performance. ASHRAE 1020-RP and 1043-RP will produce well-documented data sets containing normal and faulty data obtained from two air-handling units and one chiller. This data

along with validated simulation data would be used to assess existing FDD methods in different application areas in order to identify the performance of the methods.

Objectives: The objectives of this research are:

1. To develop a standard testing procedure and standard performance indices that can be used to assess the performance of FDD methods;
2. To assess a number of existing FDD methods for different applications to identify the strengths and weaknesses of each method.

Benefits: FDD methods have the potential to increase building energy efficiency, improve comfort and productivity, and prolong equipment life. However, poorly designed FDD methods can lead to false alarms that are also costly. Standardized testing procedures and performance indices are needed to assist developers of FDD methods in the task of testing and assessing these methods in order to produce improved FDD tools. These procedures and performance indices would also provide building owners and operators with a means of assessing the basic capabilities of the methods.

Estimated Cost: $75,000

Estimated Duration: 18 months

Methods of Publishing Research Results:

1. Detailed Reports
2. Technical Paper(s)

Appendix G.

List of Subcommittee Attendees

Dallas: February 6, 2000

Name	Technology Development	Communications and Integration	Testing and Evaluation

Members (through 4/00)			
Jim Braun	x	x	X
Todd Rossi	x	x	X
Les Norford	x	x	X
Michael Kintner-Meyer	x	x	X
J. Carlos Haiad	x	x	X
Curt Klaassen	x	x	X
John House	x	x	X
Steve Blanc	x	x	X
Mark Breuker	X	x	X
Barry Bridges	X		

James Gartner			
John Seem			
Corresponding members			
George Kelly (CM)	x	x	X
Carol Lomonaco (CM)	x	x	X
David Kahn (CM)			
Brian Kammers (CM)	x	X	
Jim Winston (CM)			
Philip Haves (CM) (int'l member)	x		
Arthur Dexter (CM) (int'l member)	x	x	X
Charles Culp (CM)			

John Mitchell (CM)	x		X
Natascha Castro (CM)	x	x	X
Robert Old (CM)			
Patrick O'Neill (CM)			
Mark Bailey (CM)			
Tom Engbring (CM)			
Ron Nelson (CM)			
Barry Reardon (CM)			
Meli Sylianou (CM)			
Michael Brandemuehl(CM)			
Visitors			
Gene Strehlow	X		X
Srinivas Katipamula			X

Peter Amstrong			X
Osman Ahmed	X	X	
John Phelan			X
Ian McIntosh		X	X
J.R. Anderson			X
J.C. Visier	X	X	X
Kim Barker	X		
Jeff Haberl	X	X	
Fred Buhl	X		
Hanjin Mao	X	X	
Agami Reddy		X	
Tom Webster		X	